A Continuum From Pure to Synchrony Effects in Motor Cortex Spike-Triggered Averages of Rectified Electromyographic Activity during Individuated Finger Movements

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1. Abstract

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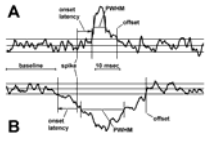
In spike-triggered averages (SpikeTAs) of rectified electromyographic activity (EMG), pure post-spike effects and synchrony effects typically are considered categorically distinct. Pure effects have onset latencies consistent with relatively direct, particularly monosynaptic, connections from the recorded trigger neuron to the motoneuron pool. Synchrony effects, in contrast, have features indicating that other neurons with connections to the motoneuron pool discharged spikes synchronized with those of the trigger neuron. Synchrony effects show an onset that occurs too early after the trigger neuron spikes to have resulted even from monosynaptic connections, and/or the peak may be too wide to attribute to EPSPs from the trigger neuron alone.

We recorded single neurons in the primary motor cortex (M1) simultaneously with EMG from 8 to 16 forearm and hand muscles in 3 monkeys performing 6 to 12 individuated finger and wrist movements. Quantitative evaluation of significant SpikeTA effects in these monkeys revealed no categorical distinction between pure and synchrony effects based on onset latency, peak width at half maximum (PWHM), or the two parameters combined. For analysis, we defined pure effects as those with both onset latency > 5 msec and PWHM < 9 msec; all other effects were considered synchrony effects. Synchrony effects generally were larger than pure effects. Many M1 neurons produced pure effects in some muscles while producing synchrony effects in others. M1 neurons producing no effects, only pure effects, only synchrony effects, or both pure and synchrony effects did not fall into different groups based on discharge characteristics during individuated finger movements, nor were these three groups spatially segregated in the M1 hand representation.

Taken together, these observations suggest a continuum from pure to synchrony SpikeTA effects. Neurons producing pure and synchrony SpikeTA effects may be drawn from similar populations in M1.

Support: NS27686.

2. Pure and Synchrony SpikeTA Effects: Discrete Categories Or Continuous Spectrum?

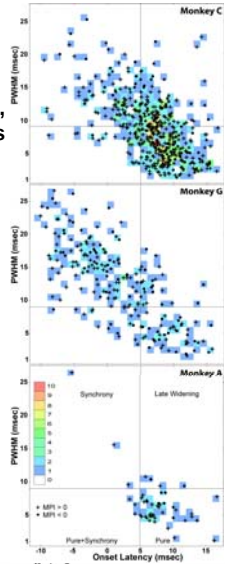


A. Pure post-spike facilitation

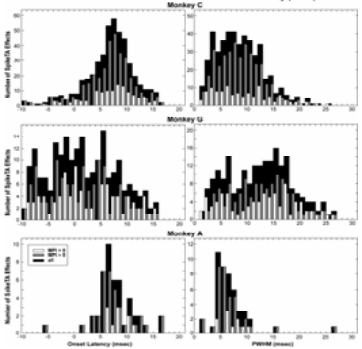
B. Synchrony Suppression

For each SpikeTA effect, we measured onset latency, peak width at half maximum (PWHM), and mean percent increase above baseline from onset to offset

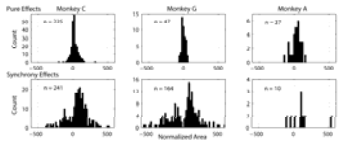
3. Onset Latency and Peak Width: Continuous, Not Bimodal, Distributions



We used onset latency > 5 msec and PWHM < 9 msec (cross-hairs) to define pure post-spike effects (lower right quadrants). These criteria also suggest three other categories—pure+synchrony, synchrony, and late widening effects—all of which were considered here to include features of synchrony.

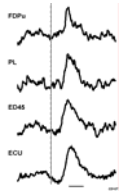


4. Synchrony effects often are larger than pure effects

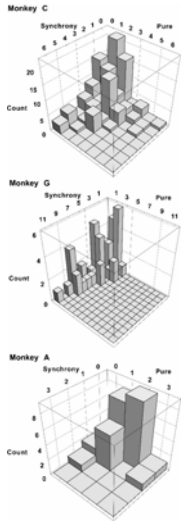


For each SpikeTA effect, normalized area was calculated as the mean percent increase times the duration from onset to offset.

5. The same M1 neuron can produce both pure and synchrony effects

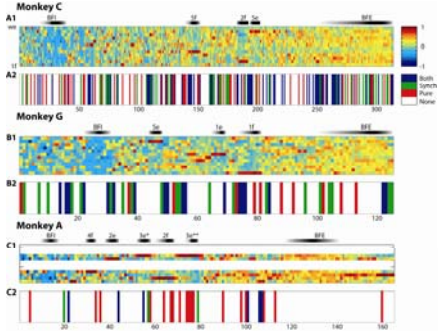


Of these SpikeTA effects produced in 4 different muscles by the same M1 neuron, the effect in FDPu is a pure post-spike effect, but the PWHM of the other 3 classifies them as synchrony (late widening) effects.



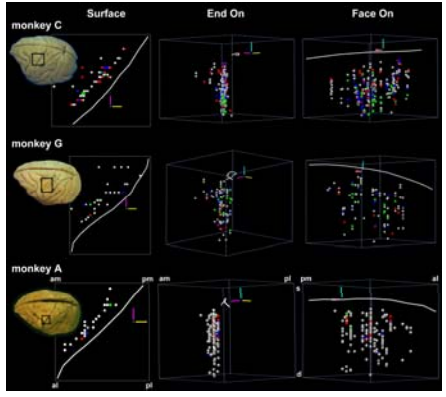
Two-dimensional histograms show the number of M1 neurons producing different numbers of pure and synchrony effects.

6. Similar activity patterns in M1 neurons that produce pure and synchrony effects



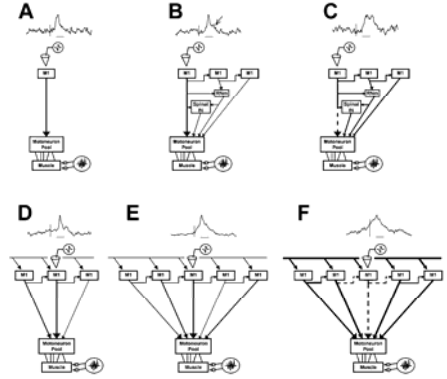
Cluster analyses show that M1 neurons with all different types of activity patterns during finger movements may produce only pure effects, only synchrony effects, or both.

7. Similar spatial location of M1 neurons that produce pure and synchrony effects



Spatial reconstruction shows that M1 neurons which produce only pure effects, only synchrony effects, or both, all are intermingled.

8. Potential mechanisms for producing a continuum from pure to synchrony SpikeTA effects



Each frame shows an actual SpikeTA effect above and a schematic potential mechanism below. Horizontal bars beneath the SpikeTA effects represent 10 msec; vertical bars indicate spike onset time:

A. A pure post-spike effect

B. A pure post-spike effect with a following tail

C. A late widening effect

D. A pure+synchrony effect

E. Another pure+synchrony effect, with a larger synchrony base

F. A broad synchrony effect

9. Conclusions

1. **Rather than showing discrete categories—pure post-spike effects or synchrony effects—SpikeTA effects present a continuous spectrum.**

2. **The spike times of M1 neurons that produce synchrony effects may mark, on average, the arrival of more excitation in the motoneuron pool time-locked to the discharge of the trigger neuron than the spikes of a CM cell which produces a pure post-spike effect.**

3. **Many SpikeTA effects suggest a mixture of monosynaptic input from a cortico-motoneuronal trigger neuron, plus additional inputs from other neurons that arrive in the same motoneuron pool synchronized with spikes of the trigger neuron.**

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